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Optimization of Mulching for Growth and Yield of Strawberry Genotypes in a Subtropical Region

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Strawberry is mainly a temperate fruit crop but grow in tropical and sub-tropical regions due to the development of day-neutral varieties. Mulching plays an important role in adaptability, performance, and yield. However, there has been no report describing the performance of strawberry genotypes with mulching practices in Bangladesh. Therefore, this research was aimed at determining the impact of mulching on morpho-physiology, yield and yield attributes. The study was two factorial RCBD with three replications with six genotypes. Various morph-physiological, biochemical and yield attributing data were recorded. Mass distribution and pigments content of the leaves of American festival and BARI 1 decreased in comparison to Linosa and Rabi 3. Genotype Linosa provides fruit for longer periods followed by BARI 1 and Rabi 3 under mulch condition while Sweet Charlie does opposite. However, sugar content (°Brix) was maximum in Linosa and Rabi 3 but has low level of antioxidant activity, where Rabi 3 has low level of vitamin B and C. BARI 1 has high level of Vitamin B and C with lower level of sugar content and antioxidant activity (64.75%). In this case, the American festival had the medium levels of sugar contents with balanced levels of vitamin B and C and antioxidant activity Among all the genotypes, the Sweet Charlie has the highest level of antioxidant activity. Although the BARI 1 with mulches provided better yield despite of heat sensitivity but Rabi 3 with mulches showed the best performance in terms of its response in growth, yield and biochemical parameters compared to rest of the genotypes.

Keywords: Morphophysiology, intercultural operations, organic mulch, soil microbial biomass, nutrient cycling.

INTRODUCTION

Strawberries are mainly a temperate fruit crop with a short day nature which are now also grown in tropical and sub-tropical regions (Pandey et al., 2015). There are various types of intercultural operations like mulching, weeding, irrigation, drainage, fertilization, protection of fruit etc. Among them, mulch plays an essential role in strawberry cultivation. It creates a barrier between the soil and the plants, which protects the fruits from rotting, pests, and diseases. Mulching helps regulate soil temperature and retain moisture. It also influences microbial biomass and supports the balance of soil organic carbon. Moreover, mulch improves nutrient cycling and boosts soil enzyme activity and contributes to better soil structure by enhancing aggregate stability and effectively reduces weed growth. Different types of mulch, like paddy straw, wheat straw, dry grass, transparent polyethylene, black polyethylene, green polyethylene, red polyethylene, pine needles, coconut husk etc. are used in strawberry production (Wang et al., 2019; Bakshi et al., 2014; Kumar et al., 2012). The significance of mulch in strawberry production is undeniable. Strawberries are rich in a wide variety of nutritive compounds such as sugars, vitamins, and minerals, as well as non-nutritive, bioactive compounds such as flavonoids, anthocyanins and phenolic acids, which are effective for human health and the prevention of disease (Afrin et al., 2016; Giampieri et al., 2015). Strawberry cultivation in Bangladesh has started to gain popularity. Because of this popularity, the total yearly production is rising day by day. According to the Bangladesh Strawberry Association, in the year 2015-16, around 6,500 bighas of land had been used for strawberry cultivation, with Rajshahi district having the most significant strawberry cultivation compared to other districts. Due to its comparatively cool climate compared to other areas of Bangladesh, the northern region of the country may be suited for strawberry (Rannu et al., 2018). In 2019-20, the Department of Agricultural Extension reported that locally, from 64 ha of land, 286 tons of strawberries were produced,

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which made about Tk. 7.2 crore in profit (Saha et al., 2022). To meet rising demand, Bangladeshi institutes released varieties like BARI Strawberry-1, Rabi series, FTIP-BAU strawberry, BADC strawberry, FA 008, Festival, and Camarosa (Rahman, 2011; Rahman et al., 2013). However, commercial strawberry production is still absent in the Sylhet region. This absence can be attributed to a range of factors. Excessive rainfall and rising temperatures create unfavorable conditions for cultivation causing root damage, diseases, poor fruit quality, and reduced yield. Acidic soil and the inefficient use of available arable land further complicate matters. The lack of organized collection and proper documentation of genotypes from different nurseries, along with the unavailability of suitable varieties, hampers progress. Moreover, many farmers lack the technical skills necessary for effective management and intercultural practices. The highly perishable nature of strawberries presents additional challenges in handling and storage.

Finally, inadequate market infrastructure and limited interest among local growers continue to obstruct the development of this sector. However, the demand for strawberries is increasing day by day. Therefore, identifying suitable strawberry genotypes that can thrive in the Sylhet region's weather is essential. By cultivating these genotypes on unutilized cultivable land, there is great potential to expand strawberry production on a large scale. This development could help meet the nutritional needs of the local population, boost economic growth, and improve the socio-economic status of the community. Additionally, increased production would create opportunities for exporting strawberries abroad, further enhancing income and development in the region. Therefore, this study was carried out to know the impact of mulching on growth, and yield of Strawberry.

MATERIALS AND METHODS

***Experimental site and duration*:** The experimental site was conducted at the field site of the Department of Crop Botany and Tea Production Technology, Sylhet Agricultural University, Sylhet-3100, during the period from November 24, 2022, to March 15, 2023. The field was located at $23^0 57'$ to $25^0 13'$ north latitude and $90^0 56'$ to $92^0 21'$ east longitude.

***Climatic condition of the experimental site*:** The weather data, like maximum and minimum temperatures and relative humidity were collected every 1-hour interval in a day using a data logger.

Edaphic condition of the experimental site is given in Table 1.

Table 1. Soil characteristics of the experimental site.

Soil characteristics	Range
Nature	Acidic
pH	5.85-6.01
Moisture content (%)	16.6-16.9
Electrical conductivity (µS/cm)	21.4-26.8
Total dissolved solids (mg/L)	14-17.5
Soil organic matter (%)	2.8-3.2

***Experimental design*:** The experiment was laid out with two factorial RCBD (randomized complete block design) with three replications. They are as follows:

Factor A: strawberry genotypes -

- Linosa (G1)
- BARI 1 (G2)
- Sweet Charlie (G3)
- Sweetheart (G4)
- American festival (G5)
- Rabi 3 (G6)

Factor B: Mulching

- Black mulch (with mulch, WM)
- Control (without mulch, WOM)

***Layout*:** The total number of plots was 36 where per plot size was 1.5 m*1.2 m = 1.8 m^2. The space between plots were 40 cm. The plants were spaced at 40 cm and 30 cm between row to row and plant to plant with four rows of plants with four plants in each row in each plot.

***Collection of planting material*:** Six (6) different genotypes were identified, collected from different local nurseries and planted in the field based on salient morphological characteristics (Table 2)

***Preparation of field and Intercultural operation*:** Were done according to protocol stated by Chowdhury and Hassan (2013).

Table 2. Morphological description of six strawberry genotypes.

Genotype(s)	Growth	Leaf size	Petiole length	Leaf color	Leaf type	Leaf Roughness	Propagation
G1	High	Large	Long	Green	Simple, Palmately compound	Smooth	Runner, Sucker
G2	Low	Large	Long	Light Green	Palmately compound	Rough	Runner, Sucker
G3	High	Medium	Long	Deep green	Palmately compound	Rough	Runner, Sucker
G4	Moderate	Small	Medium	Deep green	Palmately compound	Very rough	Sucker
G5	Low	Medium	Medium	Light green	Simple, Palmately compound	Very rough	Sucker
G6	High	Large	Long	Very deep green	Palmately compound	Smooth	Runner, Sucker

NB: The measuring parameters indicate the comparative growth, size, length, and roughness among the 6 genotypes. (G1=Linosa, G2=BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3)

***Harvesting of fruit*:** The fruit harvest started on 4th February 2023 when the fruit become red in color (minimum 80% of fruit body) with waxy layer on its surface.

***Data collection*:** For data collection three plants from each replication of 6 genotypes were selected. Their morphological (both vegetative, reproductive), physiological and biochemical data were collected. The morphological data was taken at 10 days interval and the physiological and biological data were taken at the final week.

Morphological study

***Vegetative growth*:** Various morphological characteristics like plant height (cm), Crown diameter (cm), no. of leaf, petiole length (cm), leaf area (cm^2), SPAD, no. of sucker, no. of runner, root length (cm) was taken at 10 days interval after planting by a meter scale. SPAD (SPAD 502) meter was used for measuring the greenness of the leaves.

***Reproductive growth*:** The date of first flowering, days required for fruiting, fruiting duration, days required for ripening, date of first fruiting of each genotype were recorded. During the fruiting period, some fruits per replication were sampled from each genotype to determine traits such as fruit weight (g), width (cm), length (cm), and brix content. Besides them no of fruit per plot, no of fruit per plant, total weight of fruit per plant (g), total weight of fruit per plot (g) were also determined. Fruit habits were monitored over the year.

***Physiological study*:** Chlorophyll a (mg/g), chlorophyll b (mg/g), carotenoids (mg/g), total chlorophyll (mg/g), β-carotene (mg.100 ml^{-1}), lycopene (mg 100ml^{-1}), fresh weight (g), dry weight (g), %DM of leaf were taken as physiological parameters of leaves.

In case of fruits, various physiological parameters like Chlorophyll a (mg/g), chlorophyll b (mg/g), carotenoids (mg/g), total chlorophyll (mg/g), fresh weight (g), dry weight (g), %DM of fruit were taken.

***Biochemical study*:** Antioxidant (%Inhibition of DPPH radical activity), ash weight of fruit (g), %ash fresh weight basis, % ash dry weight basis, vitamin B complex (B1, B2) (mg/ml), vitamin C (mg/ml) were determined.

***Determination of vitamin C*:** Vitamin C was determined according to Salkic et al. (2009).

***Determination of vitamin B*:** Vitamin B was determined according to Fernandes et al. (2016).

***Determination of pigments of fruits*:** Chlorophyll content and carotenoids of fruits was determined according to Porra et al. (1989). Chlorophyll a, chlorophyll b, and carotenoids were calculated by the following formula according to (Lichtenthaler, 1987) with slight modifications.

$$\text{Chlorophyll a (mg g}^{-1}\text{ FW)} = [12.21\ (A_{663}) - 2.81\ (A_{646})] \times [V/(1000 \times W)]$$

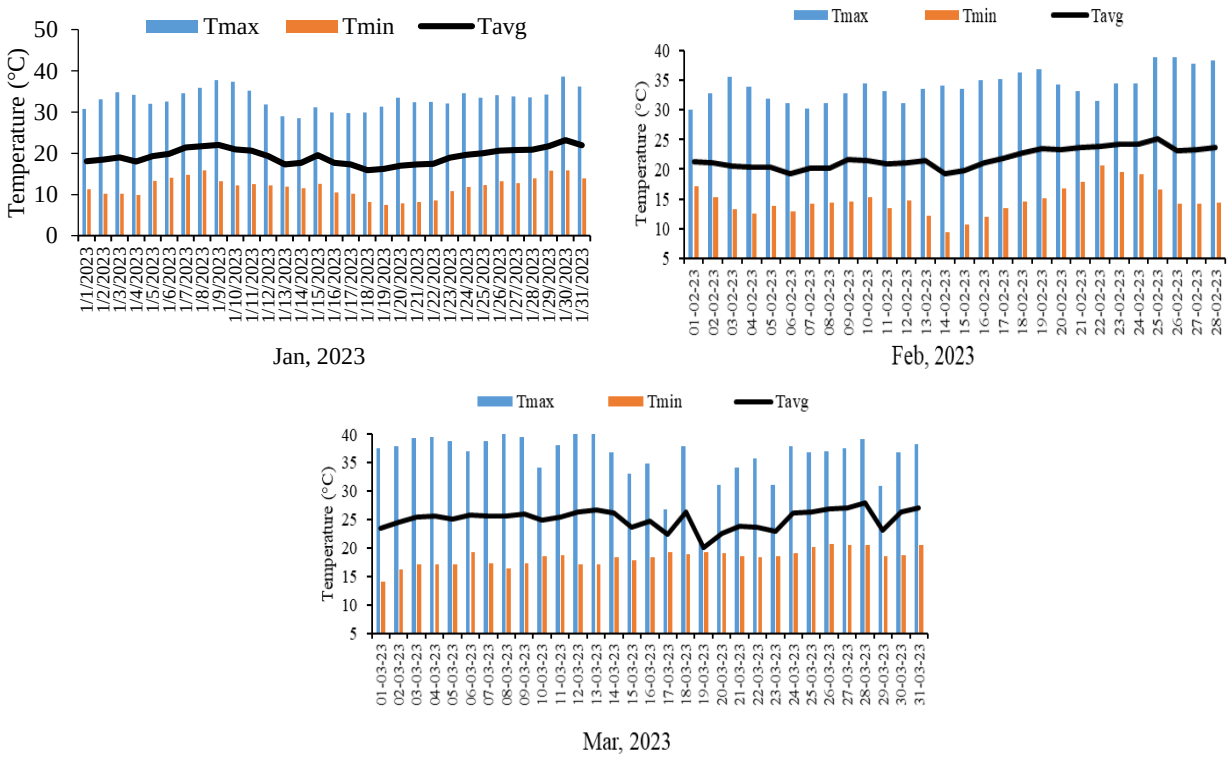


Figure 1. Maximum, minimum and average monthly air temperature during the experimental period between January 2023 to March 2023 at 1-hour interval at Sylhet Agricultural University, Sylhet-3100.

Chlorophyll b (mg g^{-1} FW)
$$= [20.13 (A_{646}) - 5.03 (A_{663})] \times [V/(1000 \times W)]$$

Carotenoids (mg g^{-1} FW)
$$= [\{1000 (A_{470}) - 3.27 (Chl\ a) - 104 (Chl\ b)\}/229] \times [V/(1000 \times W)]$$

Where, V = Volume of acetone used (ml) and W = Weight of fresh leaf sample (g)

The total chlorophyll was calculated by the following formula according to (Lichtenthaler, 1987) with slight modification.

Total Chlorophyll (mg g^{-1} FW)
$$= [8.02 (A_{663}) + 20.2 (A_{646})] \times [V/(1000 \times W)]$$

***Determination of pigments of leaves*:** Leaf pigments were determined at final week of March according to Porra et al. (1989).

***Determination of antioxidant*:** The total antioxidant activity was determined according to Kavaz D and Faraj Reke (2023) where the 1, 1-diphenyl- 2-picrylhydrazyl (DPPH) was used for free radical scavenging method.

***Statistical analysis*:** The means were calculated by averaging the values of three replications. Then the standard deviation and standard error of mean was calculated. Two-way analysis of variance (ANOVA) was performed to test the difference among the genotypes. If significant effects were found, means were separated by Least Significant Differences (Gomez & Gomez, 1984).

RESULTS

Environmental data

***Maximum, Minimum and average daily air temperature (°C)*:** The presented graph (Fig. 1) shows the daily maximum, minimum, and average temperature for the month of January, February, and March 2023 covering the entire cultivating period of the genotypes after the establishment in the field.

***Maximum, Minimum and average daily Relative Humidity (%)*:** The presented graph (Fig. 2) shows the daily maximum, minimum, and average relative humidity for the month of January, February, and March 2023 covering the entire cultivating period of the genotypes after the establishment in the field.

***Plant height (cm)*:** The interaction of genotypes with and without mulch contained results that were statistically nonsignificant.

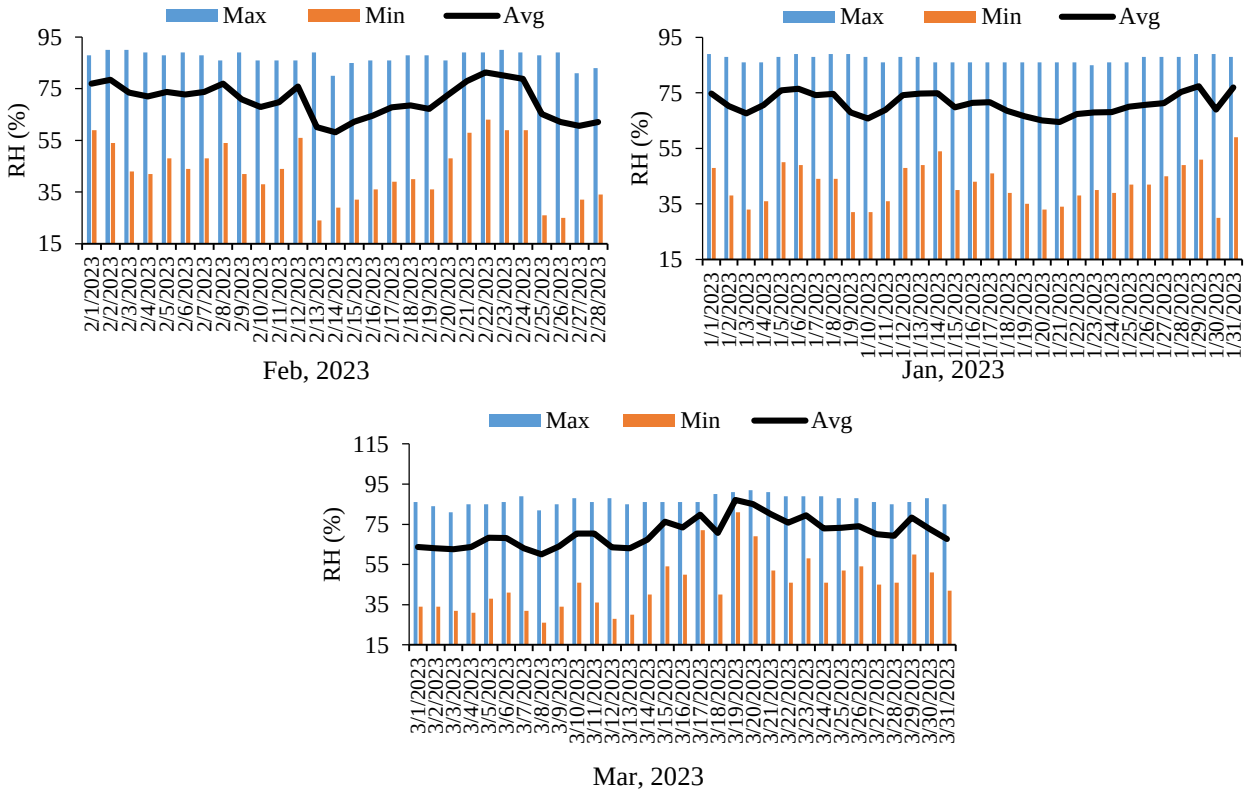


Figure 2. Maximum, minimum and average monthly relative humidity during the experimental period between January 2023 to March 2023 at 1-hour interval at Sylhet Agricultural University, Sylhet-3100. Morphological growth difference of six strawberry genotypes

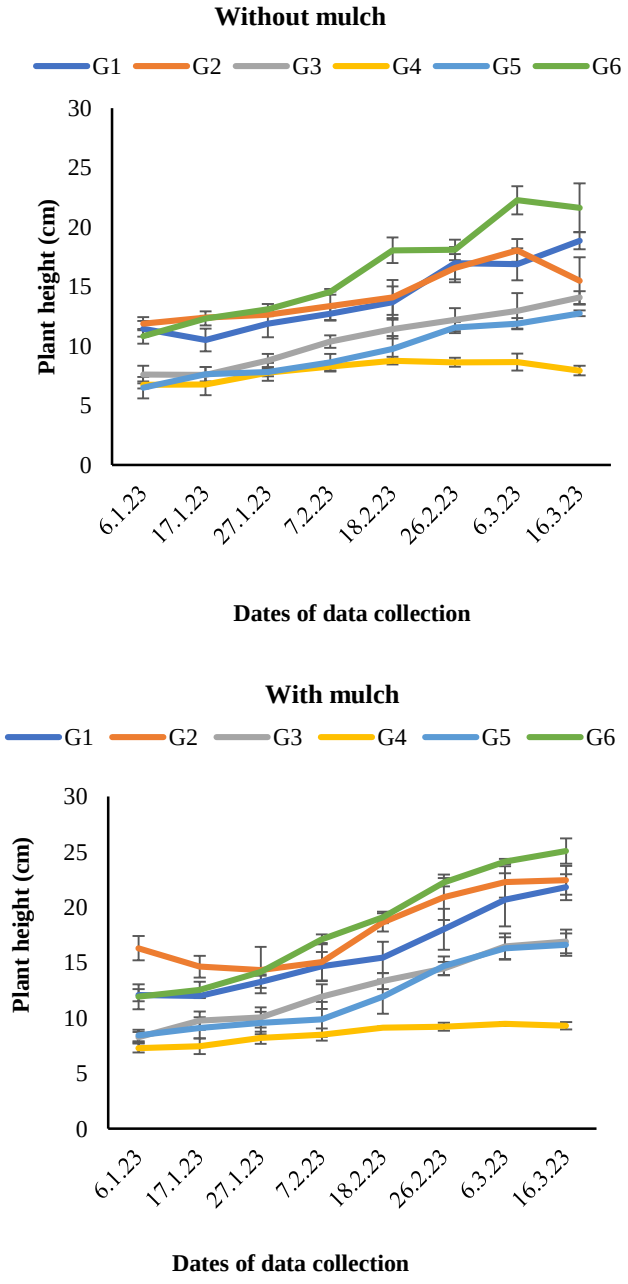


Figure 3. Plant height (cm) of six strawberry genotypes from January to March (G1=Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

***Crown diameter (cm)*:** It was also observed that the genotype-mulching interaction impact was not statistically significant.

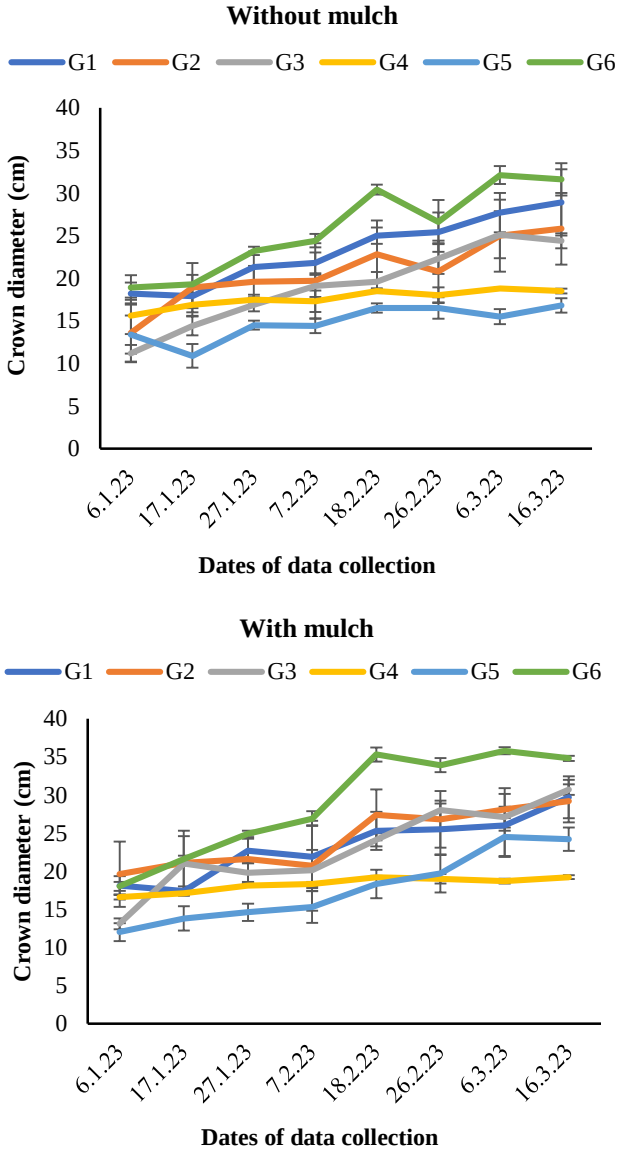
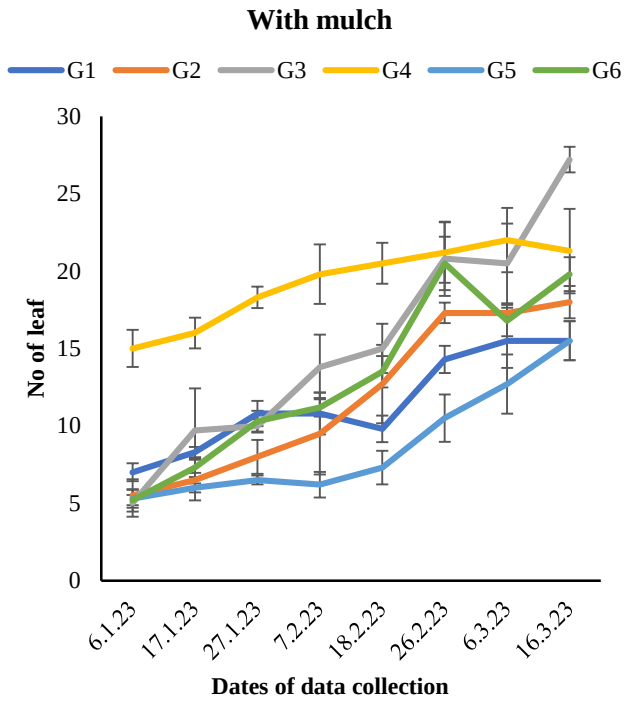


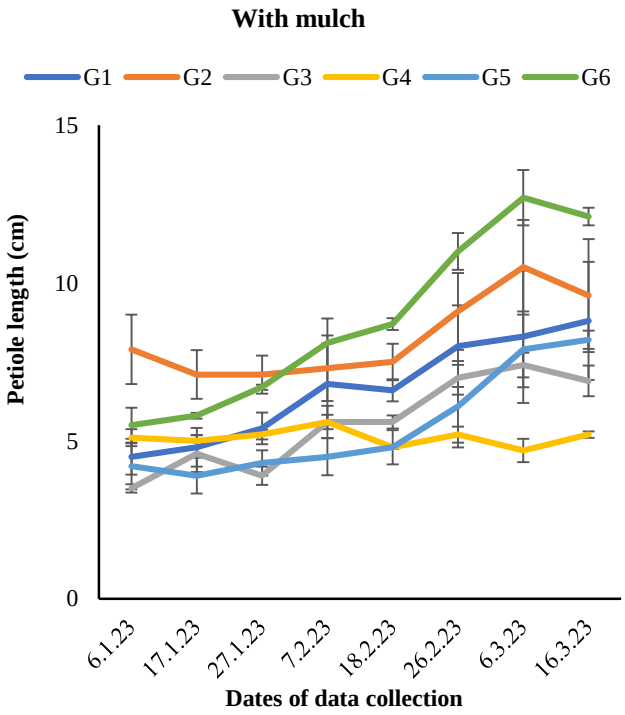
Figure 4. Crown diameter (cm) of six strawberry genotypes from January to March (G1=Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

***Number of leaves*:** There were statistical similarities in both the interactions with mulch and without mulch with genotypes.

***Petiole length (cm)*:** In instances of interaction, the petiole lengths of the strawberry genotypes did not significantly differ from one another.

***Leaf area (cm^2)*:** In case of interaction there was no lowest significant variance was found.





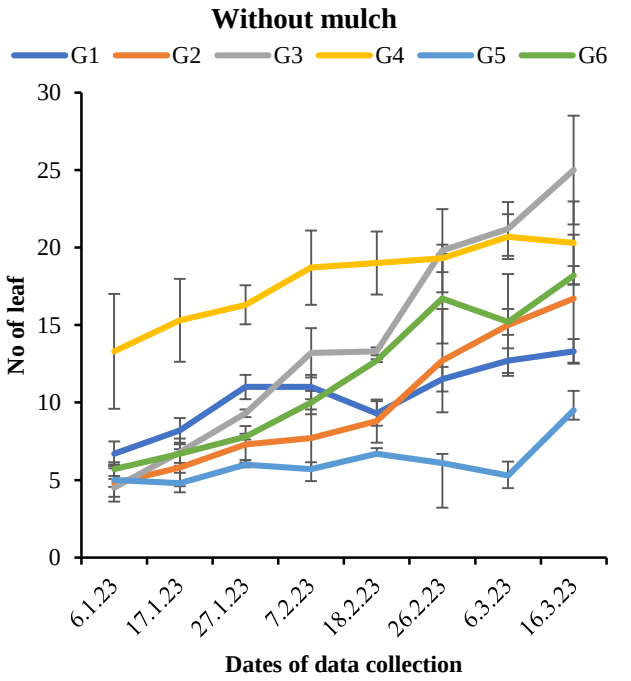


Figure 5. Number of leaves of the six strawberry genotypes from January to March (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

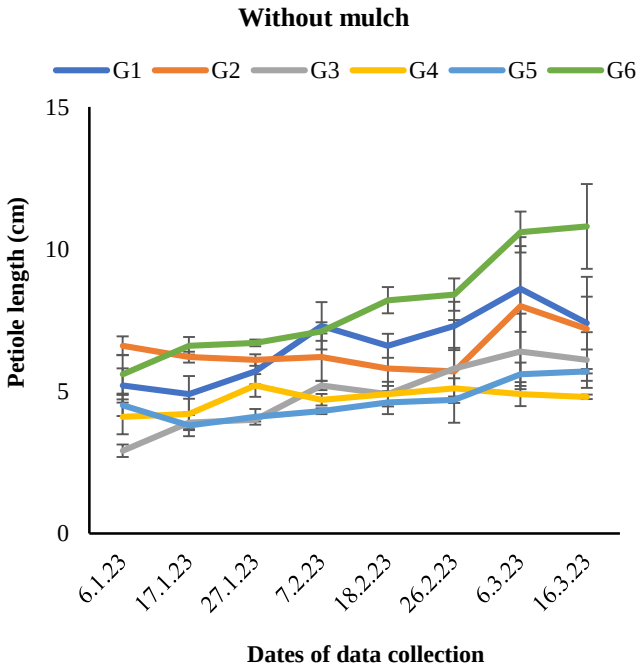


Figure 6. Petiole length (cm) of the six strawberry genotypes from January to March (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

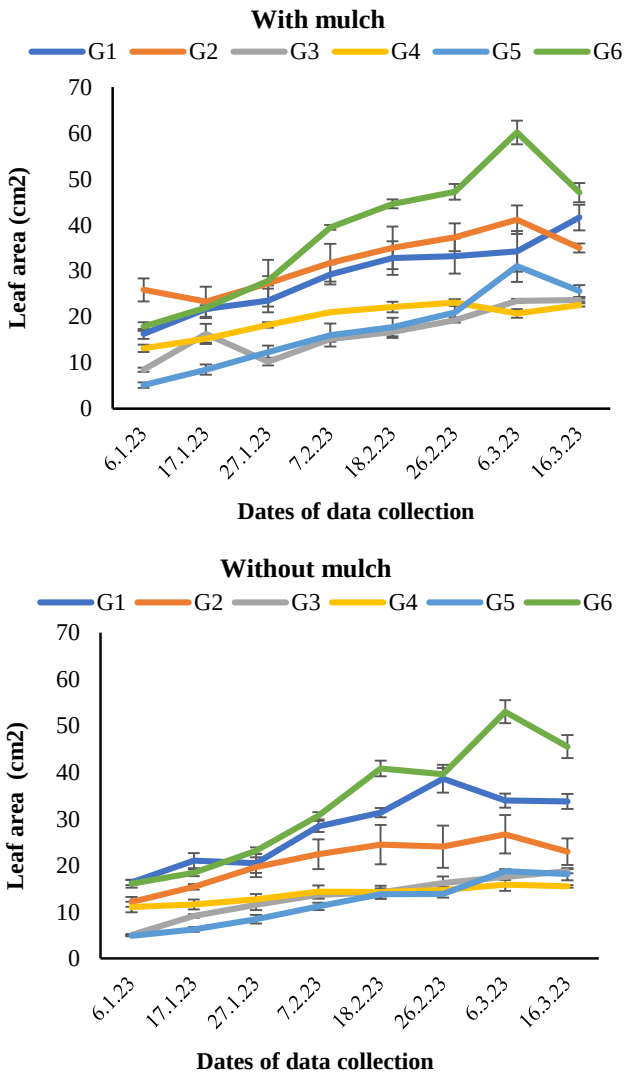


Figure 7. Leaf area (cm^2) of the six strawberry genotypes from January to March (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

***Leaf greenness (SPAD)*:** The Sweetheart (G4) genotype in mulch had the highest leaf greenness through the whole cultivation period (Fig.8). But in without mulch initially the highest value was observed in Linosa (G1) but as the day passed, Sweetheart (G4) had the greener leaves compared to others. There was very little difference in the SPAD value among all genotypes in the month of March, and American festival (G5) had the smallest leaf greenness in both mulching. The interaction of genotypes with and without mulch did not differ significantly.

***Root length (cm)*:** The graph (Fig.9) showed the significant variation of root length among the strawberry genotypes where the highest root length was observed in Rabi 3 (G6) genotypes and BARI 1 (G2) had the lowest root length compared to the others. In case of mulching, the largest root length was found with mulch rather than without mulch. Statistical differences were observed in root length in the interaction of genotypes with and without mulch. The deep-rooted plant was found in Rabi 3 (G6) genotypes in mulch, and the shallow-rooted plant was observed in BARI 1 (G2) and American festival (G5) genotypes without mulch. Statistically, American festival (G5) had the same root length with and without mulch.

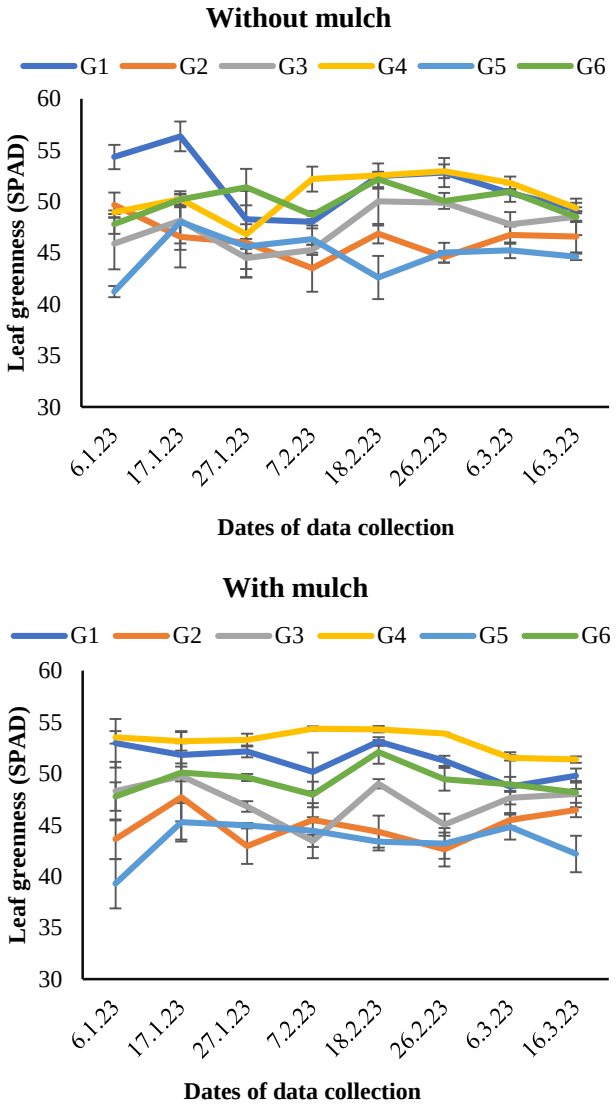


Figure 8. Leaf greenness (SPAD) of the six strawberry genotypes from January to March (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

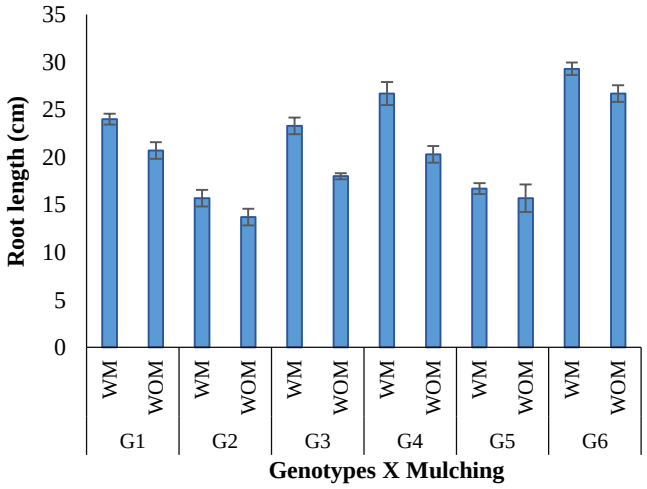


Figure 9. Root length (cm) of the six strawberry genotypes under mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

***No. of runner and sucker*:** Significant variations were found in the number of runners and suckers (Fig. 10). The highest number of runners was found in the Rabi 3 (G6) (37) and lowest in Linosa (G1) (18.5) genotype with mulch while there was no runner found in the genotype Sweetheart (G4) and American festival (G5) in both treatments. In case of suckers, the Sweetheart (G4) genotype produced the highest suckers in mulch and in without mulch genotype American festival (G5) produced no suckers compared to others. The ratio of suckers compared to runners was very low.

Physiological growth difference of six strawberry genotypes

***Biomass distribution in leaf*:** Significant differences were observed in both fresh and dry weights of the petiole and leaf lamina, but the %DM of the petiole and leaf lamina had a non-significant effect on genotypes (Table 3). The leaves of Rabi 3 (G6) genotype had the highest fresh as well as dry weight, and the lowest weight was found in the American festival (G5) genotype. The alternative scenario was found in case of %DM, where the highest value was found in the American

Table 3. Biomass distribution in leaf (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Petiole			Leaf lamina		
	Fresh weight (g)	Dry weight (g)	%DM	Fresh weight (g)	Dry weight (g)	%DM
Genotypes						
G1	1.53±0.35 a	0.51±0.08 ab	36.98±4.60	5.06±0.96 b	2.27±0.30 a	49.12±8.10
G2	1.61±0.35 a	0.51±0.10 ab	32.88±2.04	4.17±0.67 bc	1.69±0.29 b	40.76±2.04
G3	1.04±0.12 ab	0.41±0.08 bc	38.22±3.50	3.20±0.25 cd	1.40±0.10 bc	43.80±1.30
G4	1.58±0.29 a	0.41±0.04 bc	30.00±5.30	3.16±0.11 cd	1.29±0.11 bc	40.76±2.50
G5	0.62±0.09 b	0.25±0.04 c	48.41±16.6	2.20±0.39 d	0.88±0.15 c	41.40±2.20
G6	1.79±0.23 a	0.7±0.044 a	41.52±3.90	6.76±0.218 a	2.65±0.09 a	39.25±1.10
Pr (>F)	0.045	0.006	0.383	<0.001	<0.001	0.466
Mulching						
With Mulch	1.48±0.18	0.49±0.05	35.22±2.62	4.33±0.41	1.76±0.17	40.63±1.02
Without mulch	1.24±0.16	0.44±0.05	40.79±5.59	3.85±0.49	1.64±0.19	44.40±2.83
Pr (>F)	0.287	0.403	0.384	0.301	0.445	0.218
Genotypes × Mulching						
G1 × WM	1.81±0.55	0.58±0.15	32.88±2.81	5.01±1.01	2.18±0.44	43.53±0.35
G1 × WOM	1.26±0.48	0.44±0.11	41.07±9.05	5.12±1.89	2.37±0.51	54.71±17.2
G2 × WM	1.74±0.74	0.53±0.22	31.32±1.30	4.43±1.40	1.85±0.63	41.46±2.51
G2 × WOM	1.48±0.23	0.49±0.05	34.45±4.10	3.90±0.45	1.53±0.06	40.06±3.75
G3 × WM	1.21±0.21	0.52±0.15	42.38±6.45	3.56±0.39	1.53±0.13	43.36±1.30
G3 × WOM	0.88±0.07	0.30±0.01	34.06±0.94	2.83±0.14	1.26±0.13	44.24±2.55
G4 × WM	1.90±0.47	0.41±0.08	25.51±9.88	3.28±0.14	1.30±0.21	39.48±5.04
G4 × WOM	1.27±0.33	0.40±0.04	34.49±4.79	3.04±0.15	1.28±0.12	42.03±2.16
G5 × WM	0.80±0.10	0.25±0.04	31.70±1.41	2.88±0.42	1.12±0.21	38.38±1.76
G5 × WOM	0.44±0.08	0.24±0.07	65.12±33.0	1.52±0.34	0.65±0.09	44.41±3.53
G6 × WM	1.43±0.35	0.64±0.06	47.51±5.90	6.83±0.42	2.56±0.13	37.55±0.50
G6 × WOM	2.14±0.10	0.76±0.05	35.53±2.32	6.68±0.23	2.74±0.13	40.96±1.60
Pr (>F)	0.543	0.657	0.613	0.951	0.753	0.867

Table 4. Leaf pigments content of different strawberry genotypes under mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Chl-a (mg g^{-1})	Chl-b (mg g^{-1})	total chl (mg g^{-1})	Carotenoid (mg g^{-1})	β-carotene (mg. 100 ml^{-1})	Lycopene (mg 100ml^{-1})
Genotypes						
G1	1.756±0.064ab	1.211±0.127a	3.177±0.089a	0.441±0.071ab	2.221±0.139a	0.300±0.037b
G2	1.229±0.062c	0.456±0.039b	1.763±0.119c	0.312±0.034c	1.605±0.115b	0.234±0.053bc
G3	1.714±0.066ab	1.314±0.093a	3.526±0.124a	0.293±0.021c	2.417±0.147a	0.253±0.038bc
G4	1.955±0.193a	1.470±0.185a	3.466±0.181a	0.362±0.035bc	2.065±0.088a	0.191±0.010c
G5	1.461±0.075bc	0.530±0.085b	2.246±0.071b	0.529±0.016a	1.698±0.076b	0.055±0.007d
G6	1.647±0.165b	1.451±0.159a	3.294±0.147a	0.376±0.08bc	2.36±0.185a	0.498±0.098a
Pr (>F)	0.001	<0.001	<0.001	0.009	<0.001	<0.001
Mulching						
With Mulch	1.471a±0.071	0.917±0.096a	2.8.00±0.161a	0.341±0.034a	1.965±0.093	0.191±0.02a
Without mulch	1.767b±0.083	1.228±0.133b	3.024±0.186b	0.43±0.028b	2.156±0.108	0.319±0.052b
Pr (>F)	0.002	<0.001	0.043	0.021	0.072	<0.001
Genotypes × Mulching						
G1 × WM	1.69±0.033	1.057±0.195c	3.103±0.180	0.436±0.154	2.117±0.209	0.234±0.008b-d
G1 × WOM	1.8±0.117	1.366±0.135bc	3.250±0.038	0.446±0.039	2.325±0.205	0.366±0.048b
G2 × WM	1.113±0.071	0.388±0.043d	1.700±0.193	0.268±0.014	1.473±0.191	0.139±0.028de
G2 × WOM	1.345±0.03	0.524±0.034d	1.826±0.171	0.356±0.059	1.737±0.112	0.329±0.066bc
G3 × WM	1.632±0.089	1.266±0.192c	3.361±0.196	0.282±0.025	2.184±0.206	0.207±0.013cd
G3 × WOM	1.795±0.083	1.363±0.064bc	3.691±0.103	0.304±0.038	2.651±0.105	0.298±0.071bc
G4 × WM	1.677±0.255	1.085±0.143c	3.294±0.275	0.293±0.028	2.161±0.114	0.191±0.012c-e
G4 × WOM	2.232±0.209	1.856±0.051a	3.637±0.242	0.430±0.023	1.968±0.127	0.190±0.018c-e
G5 × WM	1.431±0.078	0.554±0.153d	2.279±0.088	0.530±0.035	1.715±0.080	0.054±0.005e
G5 × WOM	1.49±0.146	0.507±0.110d	2.213±0.127	0.529±0.005	1.680±0.148	0.055±0.015e
G6 × WM	1.355±0.192	1.151±0.180c	3.064±0.154	0.240±0.005	2.142±0.283	0.317±0.02bc
G6 × WOM	1.938±0.12	1.750±0.067ab	3.523±0.179	0.512±0.115	2.577±0.207	0.678±0.121a
Pr (>F)	0.350	0.041	0.733	0.245	0.386	0.014

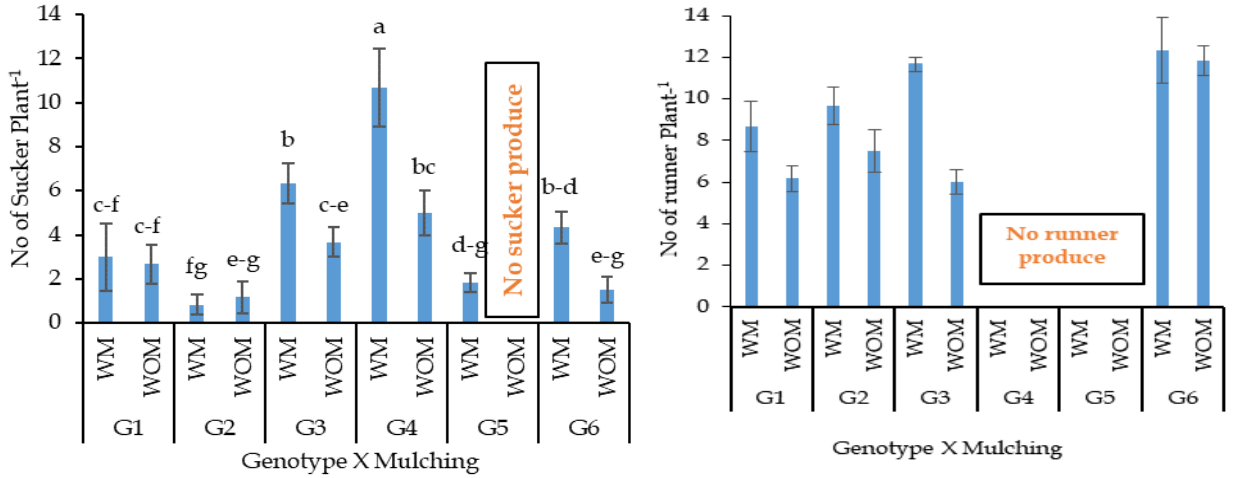


Figure 10. No of runner and sucker of the six strawberry genotypes under mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

festival (G5) genotype. The lowest %DM of petiole was observed in the Sweetheart (G4) (30) genotype, and Rabi 3 (G6) (39.25) had the lowest %DM of leaf lamina**.** The treatment and interaction of genotypes with and without mulch did not differ statistically. Fresh and dry weights were often seen to be highest under mulch, even though the %DM was high without mulch.

***Leaf pigments content*:** Statistical variation was found in case

of pigmentation (Table 4). Sweetheart was a better source of leaf chlorophyll pigments including chlorophyll-a, chlorophyll-b, and total chlorophyll compared to the rest of the genotypes. In case of carotenoid, statistical differences were observed in mulching. β-carotene (mg g^{-1}) did not show statistical variation in interaction between genotype and mulching. Statistical variation was observed in case of Lycopene contents.

***Yield and yield contributing characters*:** The yield and yield contributing character were recorded upon reproduction of the plants. The obtained data was processed and the findings are described in Table 5-8.

Table 5. Fruiting morphology of different strawberry genotypes (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4= Sweetheart, G5= American festival, G6= Rabi 3).

Genotype(s)	Bearing habit	Fruit size	Fruit softness
G1	Ever bearing	Medium	Soft
G2	Winter bearing	Large	Medium
G3	Winter bearing	Small	Hard
G4	Ever bearing	Medium	Soft
G5	Winter bearing	Medium	Hard
G6	Winter bearing	Large	Soft

Note: The measuring parameters indicate the comparative fruit size, fruit softness among the 6 genotypes.

Duration related to fruiting

***Days to first fruit setting*:** The genotypes showed significant variation in days to first fruit setting (Table 6). The genotype Linosa (G1) had the earliest first fruit setting, which occurred 69.5 days after planting, whereas the genotype Sweet Charlie (G3) had the most recent first fruit setting, which occurred 101.8 days after planting. Without mulch, the first fruit setting took a long time (84.7 days), however it took less time with mulch (81.6 days). Fruit setting was noticed in without mulch (81.3 days) before in mulch (98.3 days). Initial fruit setting was statistically observed sooner in genotypes with mulch except for Sweetheart (G4).

***Days to fruit maturity*:** In addition, fruits of the Sweet Charlie (G3) genotype reached maturity earlier in 20.2 days than those of the Linosa (G1), BARI 1(G2), and Rabi 3 (G6) genotypes, which required roughly the same amount of time (Table 6). Fruits covered in mulch matured faster (25.6 days) than those not covered in mulch (28.7 days). For interactions between genotypes and mulch in the event of maturity, no statistical variation was found.

***Fruiting duration*:** The duration of fruiting was statistically different in that it was short in both Sweet Charlie (G3) genotypes (15 days) and long in Linosa (G1) genotypes (47.5 days) in comparison to the others (Table 6). A statistical difference between mulching with and without mulch was observed in the case of fruiting, with the absence of mulch showing shorter durations. In terms of the interaction between mulching and genotypes, statistical analysis revealed a difference where the period of the fruiting phase was lengthy in Linosa (G1) X with mulch and short periodic in Sweet Charlie (G3) genotypes without mulch.

Table 6. Days related to flowering and fruiting of different strawberry genotypes (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Days required		Fruiting duration
	First fruiting	Maturity	
Genotypes			
G1	69.5±0.76 e	30.5 ±1.23 a	47.5±0.76 a
G2	79.8±3.12 c	30.8±0.6 a	36.2±3.12 c
G3	101.8±2.83 a	25.8±0.6 b	15±3.21 e
G4	89.8±3.88 b	20.2±0.79 c	24±4.83 d
G5	77.8±1.25 d	25.8±0.87 b	38.8±0.95 b
bG6	80 ±1.06 c	29.7±1.28 a	38.5±2.09 b
Pr (>F)	<0.001	0.951	<0.001
Mulching			
With Mulch	81.6±2.76 b	25.6±0.97 b	35±3.1 a
Without mulch	84.7±2.82 a	28.7±0.96 a	31.7±2.9 b
Pr (>F)	<0.001	0.951	<0.001
Genotypes × Mulching			
G1 × WM	69±1.53 h	28.7±1.86	48±1.53 a
G1 × WOM	70±0.58 h	32.3±0.88	47±0.58 a
G2 × WM	73±1.15 g	29.7±0.33	43±1.15 b
G2 × WOM	86.7±0.88 d	32.0±0.58	29.3±0.88 e
G3 × WM	95.7±0.88 c	24.7±0.33	22±1.15 f
G3 × WOM	108±1.15 a	27.0±0.58	8±1.15 h
G4 × WM	98 b±0.88 b	18.7±0.33	13.3±0.88 g
G4 × WOM	81.3±1.45 e	21.7±0.88	34.7±1.45 cd
G5 × WM	75.3±0.88 g	24.3±0.88	40.7±0.88 b
G5 × WOM	80.3±0.88 ef	27.3±0.88	37±0.58 c
G6 × WM	78±1.15 f	27.7±1.86	43±1.15 b
G6 × WOM	82±0.58 e	31.7±0.88	34±0.58 d
Pr (>F)	<0.001	0.951	<0.001

Fruit characteristics

***Fruit weight (g)*:** The fruit weight was strongly impacted by the genotypes (Table 7). The BARI 1 (G2) genotype produced the heaviest fruit (20.2 g), while the Sweet Charlie (G3) genotype produced the lightest fruit (4.2 g). The fruit weight was highest in genotypes without mulch apart from BARI 1 (G2) and Sweet Charlie (G3), where the heaviest fruit was found in genotypes with mulch.

***Fruit size (cm)*:** The length and diameter of each genotype differed considerably (Table 7). The Sweet Charlie (G3) genotype produced the shortest fruit (2.5 cm), whereas the BARI 1(G2) genotype produced the longest fruit (4.2 cm). Fruit from Sweet Charlie (G3) was the thinnest (1.9 cm), whereas fruit from BARI 1 (G2) was the thickest (3.5 cm). Only fruiting length showed significant variation, with BARI 1 (G2) X with Mulch having the longest fruiting length (4.6 cm) and Sweet Charlie (G3) having the shortest (2.5 cm), both of which interacted with and without mulch.

Table 7. Fruit characteristics of different strawberry genotypes under mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Fruit weight (g)	Fruit breadth (cm)	Fruit length (cm)
Genotypes			
G1	12.1±0.78 bc	3±0.07 b	3.3±0.12 b
G2	20.2±2.03 a	3.5±0.23 a	4.2±0.2 a
G3	4.2±0.3 d	1.9±0.14 c	2.5±0.05 c
G4	10.7±0.64 c	3.1±0.07 b	3.4±0.12 b
G5	12.6±0.99 bc	2.9±0.1 b	3.7±0.18 b
G6	14.1±1.29 b	3±0.1 b	3.6±0.14 b
Pr (>F)	<0.001	<0.001	<0.001
Mulching			
With Mulch	11.9±1.38	2.9±0.13	3.5±0.16
Without mulch	12.7±1.21	2.9±0.14	3.4±0.13
p value (>F)	0.457	0.639	0.414
Genotypes × Mulching			
G1 × WM	11.3±1.16	3±0.12	3.3 d±0.17
G1 × WOM	13±1	3.1±0.09	3.4 cd±0.22
G2 × WM	21.4±3.91	3.7±0.47	4.6 a±0.1
G2 × WOM	19.1±1.98	3.4±0.14	3.9 bc±0.23
G3 × WM	4.7±0.38	2.2±0.06	2.5 e±0.09
G3 × WOM	3.8±0.33	1.7±0.16	2.5 e±0.06
G4 × WM	9.4±0.72	3±0.12	3.5 bcd±0.21
G4 × WOM	11.9±0.12	3.2±0.03	3.3 d±0.12
G5 × WM	12.4±2.03	2.9±0.2	3.4 cd±0.22
G5 × WOM	12.9±0.84	2.9±0.08	3.9 b±0.2
G6 × WM	12.7±1.13	2.8±0.07	3.7 bcd±0.25
G6 × WOM	15.5±2.25	3.1±0.16	3.5 bcd±0.16
Pr (>F)	0.579	0.214	0.031

Fruit physiology

***Dry matter (%)*:** The genotypes dry matter content varied statistically (Table 8). Dry matter content ranged from Sweet Charlie (G3) genotype minimum. The greatest DM% was found in Linosa (G1), BARI 1(G2) and Rabi 3 (G6) genotypes with mulch. On the other hand, genotype Sweet Charlie (G3), Sweetheart (G4) and American festival (G2) showed the greatest accumulation of dry matter (%) in the absence of mulch.

***Carotenoid (mg 100 g^{-1} fw)*:** Significant difference was observed in case of genotypes and interaction with mulching treatments. Carotenoid contents ranged from 0.14-0.31 mg 100 g^{-1} in genotypes, with Rabi 3 (G6) X with Mulch and American festival (G5) X with Mulch having the slightest and peak values, correspondingly (Table 9).

***Chlorophyll pigments (mg 100 g^{-1} fw)*:** Statistical variation was found in the case of chlorophyll pigments (Table 9), in which the genotypes without mulch showed the highest chlorophyll a, chlorophyll b, and total chlorophyll content except American festival (G5) genotype, which showed a high content of chlorophyll in mulch, and Sweet Charlie (G3), which had the highest amount of chlorophyll.

Table 8. Dry matter (%) as influenced by mulches in strawberry genotypes (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Dry matter (%)
Genotypes	
G1	10.03±0.33 ab
G2	8.37±1.35 bc
G3	5.71±0.85 c
G4	10.77±1 ab
G5	11.35±1.12 a
G6	9.18±0.33 ab
Pr (>F)	0.004
Mulching	
With Mulch	9.75±0.58
Without mulch	8.71±0.73
Pr (>F)	0.182
Genotypes × Mulching	
G1 × WM	9.98±0.36
G1 × WOM	10.08±0.64
G2 × WM	7.94±0.22
G2 × WOM	8.8±2.98
G3 × WM	7.25±0.13
G3 × WOM	4.17±1.11
G4 × WM	12.33±1.35
G4 × WOM	9.2±0.86
G5 × WM	12.31±1.74
G5 × WOM	10.38±1.53
G6 × WM	8.72±0.46
G6 × WOM	9.65±0.33
Pr (>F)	0.412

Fruit quality (Biochemical)

***Total soluble solids (°Brix)*:** The total soluble solids were found to be highest in the Linosa (G1) (9.9°Brix) and Rabi 3 (G6) (10°Brix) genotypes (Table 10). All the genotypes were significantly correlated with one another except genotypes Linosa (G1) and Rabi 3 (G6). For total soluble solids (TSS ^{o}Brix) and the interaction of genotypes and mulching, there was no statistical significant change was found.

***Ash content (%)*:** Although all genotypes were statistically equivalent (Table 10), the observed values for total ash content were higher by roughly 2.2**%** in American festival (G5) genotypes and lowest in Sweet Charlie (G3) genotypes with 0.51**%**. Comparison with no mulch, the percentage of ash content was highest. Additionally, it was determined that the interaction between genotypes and mulch was not significant.

Table 9. Fruit pigments as influenced by mulches in strawberry genotypes (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart G5= American festival, G6= Rabi 3).

Treatments	Pigments (mg 100 g^{-1} fw)			
	Carotenoids	Chl-a	Chl-b	Total Chl
Genotypes				
G1	0.168±0.042 c	0.624±0.054 c	0.785±0.052	1.516±0.085 b
G2	0.268±0.015 ab	0.642±0.041bc	0.774±0.041	1.511±0.047 bc
G3	0.23±0.03 b	0.77±0.049 a	0.719±0.045	1.74±0.04 a
G4	0.135±0.022 c	0.517±0.051d	0.698±0.056	1.399±0.074 bc
G5	0.313±0.028 a	0.732±0.06 ab	0.732±0.051	1.649±0.081a
G6	0.144±0.028 c	0.61±0.066 cd	0.751±0.055	1.395±0.102 c
Pr (>F)	<0.001	<0.001	0.611	<0.001
Mulching				
With Mulch	0.189±0.026 a	0.624±0.036	0.732±0.025	1.48±0.053a
Without mulch	0.23±0.016 b	0.674±0.034	0.754±0.031	1.59±0.044b
Pr (>F)	0.009	0.091	0.501	0.003
Genotypes × Mulching				
G1 × WM	0.104±0.025 e	0.542±0.042 cd	0.719±0.065 a-d	1.391±0.12 d-f
G1 × WOM	0.232±0.064 b-d	0.705±0.08 ab	0.851±0.068 a	1.641±0.077 a-c
G2 × WM	0.291±0.015 b	0.615±0.059 bc	0.741±0.075 a-d	1.422±0.015 de
G2 × WOM	0.244±0.02 bc	0.669±0.064 bc	0.807±0.042 ab	1.599±0.055 bc
G3 × WM	0.165±0.011 de	0.712±0.063 ab	0.637±0.049 cd	1.684±0.042 ab
G3 × WOM	0.295±0.012 b	0.827±0.07 a	0.801±0.032 ab	1.795±0.057 a
G4 × WM	0.101±0.019 e	0.472±0.062 d	0.773±0.079 a-d	1.325±0.079 ef
G4 × WOM	0.169±0.031 de	0.562±0.083 cd	0.623±0.061 d	1.473±0.124 c-e
G5 × WM	0.37±0.009 a	0.833±0.064 a	0.814±0.04 a	1.803±0.06 a
G5 × WOM	0.255±0.02 bc	0.63±0.062 bc	0.649±0.067 b-d	1.495±0.076 cd
G6 × WM	0.1±0.023 e	0.571±0.093 b-d	0.709±0.057 a-d	1.252±0.032 f
G6 × WOM	0.187±0.04 cd	0.649±0.109 bc	0.792±0.101 a-c	1.538±0.175 b-d
Pr (>F)	<0.001	0.018	0.020	<0.001

Table 10. Fruit TSS (°Brix) and Ash content (%) as influenced by mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart G5= American festival, G6= Rabi 3).

Treatments	TSS (°Brix)	Ash content (%)
Genotypes		
G1	9.9±0.57 a	0.71±0.11
G2	7±0.51 b	0.57±0.09
G3	7±0.15 b	0.51±0.08
G4	7.6±0.04 b	0.99±0.21
G5	8.1±0.52 b	2.2±1.43
G6	10±0.4 a	0.69±0.08
Pr (>F)	<0.001	0.326
Mulching		
With Mulch	8.3±0.38	1.33±0.48
Without mulch	8.3±0.39	0.57±0.05
Pr (>F)	0.972	0.122
Genotypes × Mulching		
G1 × WM	10.2±0.18	0.75±0.19
G1 × WOM	9.7±1.22	0.67±0.15
G2 × WM	6.7±0.35	0.56a±0.05
G2 × WOM	7.3±1.05	0.57±0.19
G3 × WM	7.2±0.15	0.66±0.08
G3 × WOM	6.8±0.23	0.35±0.05
G4 × WM	7.6±0.06	1.46±0.12
G4 × WOM	7.6±0.07	0.53±0.05
G5 × WM	7.6±0.53	3.79±2.78
G5 × WOM	8.6±0.91	0.62±0.04
G6 × WM	10.3±0.82	0.72±0.08
G6 × WOM	9.8±0.28	0.67±0.15
Pr (>F)	0.796	0.365

***Vitamin B complex (mg 100 ml^{-1})*:** In case of vitamin B1, genotypes showed more or less good performance without mulch except Rabi 3 (G6), but significant variation was found in vitamin B2, where some genotypes showed good results with mulch and some showed good results without mulch (Table 11). The minimum values for vitamin B1 and vitamin B2 (mg 100 ml^{-1}) were 1.29 and 0.54 from Sweetheart (G4) X with Mulch, whereas the maximum values were 2.78 and 1.51 from Sweet Charlie (G3) X without Mulch and BARI 1 (G2) X without Mulch.

***Vitamin C (mg 100 ml^{-1})*:** Genotypes without mulch contained more vitamin C except for Rabi 3 (G6), which showed the highest value in mulch (Table 11). The minimum and maximum values for vitamin C were 6.62 and 14.67 mg 100 ml^{-1}, respectively, and were recorded from Rabi 3 (G6) interacting without mulch and American festival (G5) X without mulch.

***Antioxidant Activity (%)*:** The results for the radical scavenging activity are presented in Table 11 where statistical variation was found. The highest activity was observed at a concentration of 200 g/ml in the Sweet Charlie (G3) genotype (79.03%), signifying the strongest scavenging ability, whereas the minimum value was found in the genotype Rabi 3 (G6) (62.24%), signifying the least radical scavenging ability. The genotypes moreover showed good performance

Table 11. Fruit vitamins (mg 100-ml^{-1}), Antioxidant Activity (%) as influenced by mulches in genotypes (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart, G5= American festival, G6= Rabi 3).

Treatments	Vitamins (mg 100 ml^{-1})			Antioxidant Activity (%)
	Vit-B1	Vit-B2	Vit-C	
Genotypes				
G1	2.377±0.056 a	1.115±0.061 a	13.595±0.226 a	63.728±0.41 e
G2	2.106±0.166 b	1.218±0.173 a	13.503±0.546 a	64.75±0.446 d
G3	2.515±0.136 a	0.881±0.057 b	12.054±0.393 b	79.033±0.51 a
G4	1.505±0.142 c	0.622±0.06 c	12.121±0.634 b	68.795±0.513 c
G5	1.994±0.113 b	0.812±0.061b	13.257±0.698 a	76.815±0.445 b
G6	1.537±0.115 c	0.751±0.047 bc	6.836±0.127 c	62.242±0.56 f
Pr (>F)	<0.001	<0.001	<0.001	<0.001
Mulching				
With Mulch	1.859±0.087 a	0.823±0.056 a	11.148±0.503 a	68.929±1.443 a
Without mulch	2.152±0.128 b	0.976±0.076 b	12.64±0.683 b	69.525±1.734 b
Pr (>F)	<0.001	0.002	<0.001	0.035
Genotypes × Mulching				
G1 × WM	2.273±0.043 b	1.171±0.108 b	13.412±0.345 bc	64.477±0.466 f
G1 × WOM	2.481±0.056 ab	1.059±0.059 bc	13.778±0.32 ab	62.98±0.255 g
G2 × WM	1.802±0.084 c	0.928±0.132 c-e	12.374±0.316 c-e	64.51±0.394 f
G2 × WOM	2.41±0.197 b	1.508±0.218 a	14.632±0.344 a	64.99±0.884 f
G3 × WM	2.251±0.128 b	0.801±0.035 d-f	11.34±0.44 ef	78.06±0.461 b
G3 × WOM	2.78±0.077 a	0.96±0.094 b-d	12.768±0.26 b-d	80.007±0.374 a
G4 × WM	1.291±0.146 d	0.537±0.064 g	10.864±0.56 f	67.753±0.358 e
G4 × WOM	1.719±0.182 c	0.706±0.082 e-g	13.377±0.345 bc	69.837±0.323 d
G5 × WM	1.768±0.021 c	0.687±0.029 fg	11.841±0.441 d-f	75.907±0.246 c
G5 × WOM	2.219±0.112 b	0.936±0.045 cd	14.673±0.489 a	77.723±0.326 b
G6 × WM	1.769±0.094 c	0.813±0.078 d-f	7.056±0.069 g	62.87±0.835 gh
G6 × WOM	1.305±0.058 d	0.688±0.036 fg	6.615±0.166 g	61.613±0.691 h
Pr (>F)	<0.001	0.002	0.001	<0.001

in without mulch except Linosa (G1) and Rabi 3 (G6) genotypes which showed good antioxidant activity in mulch.

***Yield of different strawberry genotypes under mulches*:** The strawberry yield plot^{-1} was significantly influenced by genotype (Table 12). The BARI 1 (G2) genotype produced the maximum fruit plot^{-1} (4.78 kg), which was statistically equivalent to the Rabi 3 (G6) genotype's (4.59 kg), while the Sweet Charlie (G3) genotype produced the least (0.74 kg). In instances of mulching and the interaction between genotypes and mulching, statistical variance was discovered. The genotype BARI 1(G2) X with mulch produced the highest strawberries, 5.32 kg, while the genotype Sweet Charlie (G3) X without mulch harvested the least, 0.57 kg.

DISCUSSION

***Effect of genotype on morphological growth*:** In the present study, statistically significant differences were found in the morphological characteristics of all the genotypes. Linosa (G1), BARI 1(G2), and Rabi 3 (G6) showed good performance in terms of plant height (cm), crown diameter (cm), petiole length (cm), leaflet length (cm), leaf expansion (cm), and leaf area (cm^2). The highest number of leaves was found in Sweet Charlie (G3) and Sweetheart (G4), and the highest SPAD value was observed in Linosa (G1) and Sweetheart (G4) genotypes. In terms of root length, Rabi 3 (G6) had deep, and strong root system and BARI 1(G2) had the shallow and weak root system among all genotypes. These findings are not in accordance to (Rahman et al., 2013) where Sweet Charlie" (V6) and "Hadar" (V7) had poor adaptability and showed high mortality and poor vegetative growth due to poor adaptability of these genotypes in the sub-mountainous region of Punjab. The morphological variation was also found in the study of (Rahman et al., 2013) where FA 007 was the tallest plant, the most runners plant^1 belonged to FA 003, followed by FA 004 (68.67), while the most crown plant^1 belonged to FA 007 (15.33), followed by FA 006 (14.67). As like the present study, these studies showed variation in all the genotypes in various morphological parameters which is support the present study.

***Effect of mulches on morphological growth*:** All the plant growth characters and nutrient uptake were superior with black polyethylene mulch followed by transparent polythene, paddy straw while, plants without mulch (control) resulted

poor growth and yield (Patil et al., 2013; Kumar et al., 2011; Ngente et al., 2021). According to Casierra-Posada et al. (2011) red mulch gave results similar or better to the black control for most factors. Foliar area were highest with red mulch and lowest for silver. Singh et al. (2019) gave another perception which indicated that strawberry plants mulched with Silver-black considerably improved vegetative growth than Black-black, Red-black and Straw mulches. On the other hand, Lalk et al. (2020) observed that mulch type did not affect plant vegetative growth which did not match with the current study where it was found that all the morphological characteristics performed well in mulch treatment compared to without mulch except the SPAD value, which was highest in without mulch.

***Percentage (%) of leaf dry matter*:** According to Menzel and Smith (2014) the dry weight of leaves varied between 1.1 and 11.2 g and the dry matter distribution (%) varied from 1.42 to 47.2 in 'Festival' strawberry plants. But in the present study, the dry weight and % DM was observed separately in the petiole and leaflet of a leaf in six different strawberry genotypes (Linosa, BARI 1, Sweet Charlie, Sweetheart, American festival, Rabi 3) only for one season and statistical variation was found in case of genotypes.

***Leaf pigments content*:** According to Blanke (2000) strawberry leaves had a closer chlorophyll a:b ratio of 3-4:1, whereas the chlorophyll content of leaves varied between 1.5 and 2 mg g^{-1} FM. However, it was observed in the current study that the concentration of chlorophyll ranged between 1.70 and 3.69 mg g^{-1}. In Costa et al. (2010) it was shown that cultivar 'Camarosa' had a greater level of Chl a (1.05 mg g^{-1}), Chl b (1.35 mg g^{-1}), and total chlorophyll (2.40 mg g^{-1}) than cultivar 'Oso Grande'. Lastly, both cultivars showed higher Chl b concentrations than Chl a. But the results of the current study showed that the chl a (1.11-2.23 mg g^{-1}) level was greater than the chl b (0.39-1.86 mg g^{-1}) level which is reverse to Costa et al. (2010). In a study, ŠicŽlabur et al. (2020) found that the strawberry tree leaves' total carotenoid content ranged from 0.09 to 0.27 mg g^{-1}. The carotenoid concentration in the present study (0.24-0.53 mg g^{-1}) was significantly greater than their results. When compared to a range of carotenoids, lycopene is recognized to be the most effective singlet oxygen quencher (Durairajanayagam et al., 2014).

***Duration related to fruiting of strawberry*:** In the current investigation, it was observed that the genotype Linosa (G1) performed well in terms of initial fruiting, lengthy blooming and fruiting durations. Sweetheart (G4) genotype typically took shorter time to reach maturity. Sweet Charlie (G3) performed poorly compared to other genotypes in all of the characteristics, though. It was found that strawberry plants that were mulched performed better than those that were not, which is consistent with research by Rahman et al. (2011) that found that Camarosa treated with black polythene performed the best for the duration of strawberry flowering and fruiting. Comparing red plastic mulch to control and black plastic mulch, Sharma et al. (2013) found that the red plastic mulch considerably increased the length of blooming and fruiting as well as improved fruit set. Phet and Mpuat (2016) observed that all mulches (rice husk, white polythene, and black polythene) were superior to no mulch in terms of plant growth, yield, and quality and concurred with the current study.

***Fruit quality (Biochemical)*:** Phet and Mpuat (2016) found that Vitamin C (52.5%) was highest in case of black polythene mulch, that was significantly higher than the rest of the treatments, and the lowest Vitamin C was recorded in the case of rice husk mulch, which did not match with the present study. In the present study, it was found that the highest vitamin C content was found in American festival (G5) without mulch compared with black polythene mulch.

The vitamin B complex of six different strawberry genotypes differed significantly where the vitamin B1 and B2 ranged in 1.29-2.78 mg 100 ml^{-1} and 0.54-1.51 mg 100 ml^{-1} in the current study. Both the maximum values for vitamin B1 (2.78 mg 100 ml^{-1}) and vitamin B2 (1.51 mg 100 ml^{-1}) were obtained without mulch which was higher than Giampieri et al. (2015). Giampieri et al. (2015) estimated that fresh strawberries provide an average of 0.024 mg of thiamin (vitamin B1), 0.022 mg of riboflavin (vitamin B2) and 0.047 mg of vitamin B6.

According to Blanke (2000), strawberry fruit had a closer chlorophyll a:b ratio of 2-3:1 and contained between 0.2 and 0.6 mg of chlorophyll per g of FM. In the current investigation, it was discovered that the range of the total chlorophyll concentration was 1.25 to 1.80.

Hossain et al. (2016) observed that the number of carotenoids was found to be extremely low, ranging from 0.99 to 3.30 g per 100 g of edible fruit. Compared to their findings, the current studies carotenoid concentration was significantly higher. The concentrations of carotenoids ranged from 0.37 to 0.1 mg/100g, with the highest and lowest values, respectively, found in American festival (G5) X with Mulch and Rabi 3 (G6) X with Mulch.

According to Rahman et al. (2018), the natural antioxidants found in strawberries were widely known for their superior ability to scavenge free radicals. Ganhao et al. (2019) found that the extract's antioxidant activity increased as the absorbance declined more quickly, which was similar to the present study where DPPH (1, 1-*diphenyl*- 2-picrylhydrazyl) was used, and the antioxidant activity increased in those genotypes that had low absorbance. The % Inhibition of DPPH radical activity was high (80.01%). On the other hand, Rabi 3 (G6) had a low antioxidant content (61.61%). In the current study, the DPPH free radical scavenging activity of strawberry genotypes ranged from 61.61 to 80.01 and was generally higher than those values ranged between 42.0 ± 2.3% and 51.8 ± 5.1% reported by Ganhão et al. (2019).

***Fruit weight (g) and size (cm)*:** BARI 1 (G2) genotype produced fruit with the highest weight, length, and breadth. In

the present study, some genotypes performed better in the instance of fruit length when mulch was present, whereas others performed better when mulch was absent. In comparison to silver mulch, black plastic mulch, and no mulch (control), red plastic mulch increased the weight and length of fresh fruit (Sharma et al., 2013; Casierra-Posada et al., 2011). In contrast, Lalk et al. (2020) found that the type of mulch had no effect on the amount of berry size, which is identical to the present findings.

Table 12. Yield of different strawberry genotypes under mulches (G1= Linosa, G2= BARI 1, G3= Sweet Charlie, G4=Sweetheart G5= American festival, G6= Rabi 3).

Treatments	Total Fruit weight plot^{-1} (kg)
Genotypes	
G1	3.71±0.1 b
G2	4.78±0.26 a
G3	0.74±0.1 e
G4	1.15±0.06 d
G5	2.51±0.04 c
G6	4.59±0.12 a
Pr (>F)	<0.001
Mulching	
With Mulch	3.06±0.42 a
Without mulch	2.76±0.35 b
Pr (>F)	<0.001
Genotypes × Mulching	
G1 × WM	3.86±0.12 d
G1 × WOM	3.56±0.11 e
G2 × WM	5.32±0.16 a
G2 × WOM	4.24±0.14 c
G3 × WM	0.9±0.09 h
G3 × WOM	0.57±0.1 i
G4 × WM	1.04±0.05 gh
G4 × WOM	1.25±0.05 g
G5 × WM	2.45±0.05 f
G5 × WOM	2.58±0.04 f
G6 × WM	4.8±0.13 b
G6 × WOM	4.37±0.09 c
Pr (>F)	<0.001

***Dry matter content (%)*:** The dry matter (DM) content (%) of the four strawberry genotypes was measured by Tulipani et al. (2011) in the three phases of ripening that were chosen, and they discovered that the %DM dropped as the fruits reached the further ripening stage. For instance, mature strawberries from the cultivar "Adria" had less than half the dry matter of ripe strawberries from the selection "AN94.414.52" (4.5% and 9.3%, respectively) while they were in the third stage of ripeness. However, in the current research, the DM% was only detected during the final ripening stage, where it varied from 5.71% to 11.35%.

***Ash content (%)*:** Hossain et al. (2016) stated that ash values ranged from 0.56 ± 0.09 g to 0.81 ± 0.17 g per 100 g of edible fruit, which is greater than previously published values (Giampieri et al., 2012) and lower than the current study's range of o.51% to 2.2%.

***TSS (ºBrix)*:** The Linosa (G1) and Rabi 3 (G6) genotypes in the current study notably had the highest TSS (ºBrix) compared to the others. However, results for genotype interactions with and without mulch were found to be non-significant. 'Florida' fruits from 2019 that had been mulched with black plastic had the highest TSS concentration, while 'Winterstar' fruits that had not been mulched had the highest TSS contents, according to Abdalla et al. (2019) similar to this, Bakshi et al. (2014) discovered that black plastic mulching had greater TSS concentrations than the control or clear plastic treatments in strawberry fruits (cv. Chandler). Similar to our findings, Soliman et al. (2015) discovered significant differences in TSS contents among several strawberry cultivars grown in various mulch treatments. In the first season of their experiment, the fruits of the "Festival" and "Sweet Charlie" cultivars with black and clear mulching, respectively, had higher TSS content than the unmulched plants. In their second season, mulched (clear or black) 'Sweet Charlie' plants only had greater fruit TSS concentrations than the un-mulched treatment, whilst 'Festival' was not impacted by the mulching treatment.

***Yield (kg)*:** In the current research, the BARI 1 (G2) genotype in mulch produced the most fruits plot^{-1}. According to Abdalla et al. (2019) black plastic mulching increased fruit yields by 17-18% (in seasons 1 and 2, respectively) in the 'Winterstar' cultivar and by 49% (seasons 1 and 2) in 'Florida' as compared to unmulched plants. In cv. 'Gavuta' strawberries, mulching treatment had no discernible impact on yield, but in cv. 'Sweet Charlie' plants, mulching treatment with black plastic resulted in a significantly higher yield compared to unmulched plants. Biodegradable films like BioFlex® (P2), Bio 6, and Bio 7 films produced the largest yield and the biggest number of fruits with the best size and quality. This is consistent with other researchers' findings that strawberry plants cultivated under black, clear plastic, PBAT film mulching had much higher early yield than the un-mulched plants (Soliman et al. 2015; Kumar et al. 2011; Ngente et al. 2021). However, there were some experiments that contradicted the findings above. Mulch type apparently had no effect on strawberry fruit quality factors (Lalk et al., 2020). Silver-black mulch significantly increased the fruit yield plant^{-1} for strawberry plants compared to black, red, and straw mulches, and red mulch produced results that were comparable to or superior to the black control for the majority of parameters (Singh et al., 2019; Casierra-Posada et al., 2011) which doesn't resemble the present study.

***Conclusion*:** The results of the present study revealed that significant variation observed among the six strawberry genotypes (Linosa, BARI 1, Sweet Charlie, Sweetheart, American festival, Rabi 3) and mulching effects in respect of morphology, physiology, biochemical and yield contributing

characters. After analyzing the temperature and relative humidity, it was found that the highest temperature and lowest relative humidity were observed in the month of March, which hampered the morphological growth of strawberry plants. But the yield and yield-contributing characters were not affected by the remaining temperature and relative humidity. Heat sensitivity was present in the BARI 1 (G2) and American festival (G5) genotypes and the Sweet Charlie (G3) and Sweetheart (G4) were moderately affected by heat, while heat tolerance was observed in the Linosa (G1) and Rabi 3 (G6) genotypes. The Linosa (G1), BARI 1 (G2), and Rabi 3 (G6) performed better; and Sweet Charlie (G3), and American festival (G5) performed about averagely by showing weak vegetative growth. The Sweetheart (G4) and American festival (G5) genotype produced only suckers, but the Sweetheart (G4) had more leaves that were much greener. When comparing root length, BARI 1 (G2) had shallow and weak roots, while Rabi 3 (G6) had deep and strong root system. Except SPAD value, mulch showed good performance compared to without mulch. In case of leaf pigments, Sweetheart (G4) was a better source of leaf chlorophyll pigments in contrast to BARI 1 (G2). The Rabi 3 (G6) genotype had the highest levels of β-carotene and lycopene levels. On the other hand, BARI 1 (G2) had the lowest levels of β-carotene and Sweetheart (G4) had the lowest lycopene levels, respectively. The results for fruit vitamins and pigments showed that the American festival (G5) interaction without mulch and the Rabi 3 (G6) without mulch yielded the maximum and minimum vitamin C concentrations. Some genotypes produced good results with mulch and some produced good results without mulch for vitamin B2 and carotenoids but genotypes for vitamin B1 generally performed better without mulch. The American festival (G5) genotypes without mulch showed the highest chlorophyll a, chlorophyll b, and total chlorophyll content and lowest found in Sweetheart (G4). The Sweet Charlie (G3) X Without mulch showed the highest antioxidant activity, whereas the lowest was in the Rabi 1 (G6). The total soluble solids were found to be highest in the Linosa (G1) and Rabi 3 (G6) genotypes. In case of yield, the BARI 1(G2) genotype produced the largest fruit, but the highest amount of fruit plot^{-1} was given by Rabi 3 (G6) in mulch while the Sweet Charlie (G3) produced the smallest and least amount of fruit plot^{-1} without mulch. Analyzing all the parameters, it can be concluded that the Rabi 3 (G6) in mulch showed better performance compared to other genotypes, therefore, Rabi 3 may be the suitable genotypes for cultivation under mulching in subtropical region

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